Vibrations response of the ALBA Synchrotron Light Source accelerator and beam lines foundations.

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0.- Abstract

The stability of the experimental and accelerator foundations are one of the major importance on 3rd generation synchrotron light sources. A detailed study of the site for the Synchrotron light facility ALBA including, geotechnical characterization method and results, experimental setup for on-line long term soil monitoring and results, vibrations analysis results and the solution adopted for the foundations of the beam lines and complex of accelerators critical floor area based were presented at MEDSI 2006. After execution of the civil engineering works the results on the vibrations behavior of critical floor area are presented in detail.

1.- Introduction

The Consortium for the Construction, Equipping and Exploitation of the Synchrotron Light Laboratory (CELLS – www.cells.es), it is co-financed by the Spanish and the Catalan governments and its aim is to be responsible of the first Synchrotron Light Source Facility to be built in Spain, which name is ALBA.

ALBA is a 3 GeV complex that will consist of a 100 MeV electron linear accelerator followed by a 3 GeV booster synchrotron and finally the 3 GeV storage ring where eventually a beam of 400 mA will circulate while at the beamlines the scientists will perform their experiments. ALBA will use the so-called top-up injection mode, in which the current is kept almost constant in the storage ring by injecting currents as small as 1 mA every few minutes. In this case all elements of the Storage Ring and more importantly the beamline optical components will operate under a constant heat load to ensure proper stability of the beam at the sample position.

In this context, the building must be subservient to the technical and scientific necessities as well as accomplish requirements formulated by accelerators and experimental divisions.

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Structural stability of the critical floor area was one of the central and crucial parts of the Executive Building Project.

Along 2004, geotechnical investigations ordered by CELLS started at the selected construction site of ALBA.

Ground vibration measurements at the proposed ALBA site were carried out by Desy group specialized in detailed study of the vibrations aspects for synchrotrons lights sources at the end of 2004.

The Basic Project for the construction of the buildings and urbanization of external spaces was approved after an international review in September 2005. The Executive Project was completed last in February 2006.

The civil engineering works started on 26th May 2006.

2.- Vibrations requirements on critical floor area

The critical floor slab has an outer radius of 60 m and the inner edge is defined by the inner wall of the experimental line plus a minimum excess length of 30 cm. On the other hand, the inner edge is also defined by the layout of the deck elements of the false floor. The Critical Floor slab supports along its inner part the ALBA Tunnel with the experimental line and along its outer part the service area for the single lines. The width of the critical floor varies between 22 m and 29 m at the Linac. To avoid the transmission of vibrations from outside to the critical floor area, the slab has completely been disconnected and isolated from all other structures.

Loads and requirements

Loads acting on the critical floor slab and limitations of differential floor slab displacements as well as vibrations requirements are summarized below.

Circular ring in which requirements are applied	
Inner diameter	60 m aprox.
Outer diameter	120 m

Charges on the circular ring	
Total static charge	10.000 Tm
Distributed static charge	1,5 Tm / m^2
Maximum charge on a point	5 Tm / m^2
Dynamic charge	2 Tm

Floor differential displacements	
Slow relative displacements	< 0.25 mm/10 m/ year
	< 0.05 mm/10 m/month
	< 10 µm/10 m/ day
	< 1 µm/10 m/ hour
Maximum differential displacement over the whole perimeter	< 2.5 mm/ year

Floor deformability because of charges	On the application point	At 2 m
Static charge of 500 kg	6 µm	1 µm
Dynamic charge of 100 kg		1 µm

Vibrations		
Vertical amplitudes	< 4 µm	From 0.05 – 1 Hz
	< 0.4 µm	From 1 – 100 Hz
Horizontal amplitudes	2 µm	

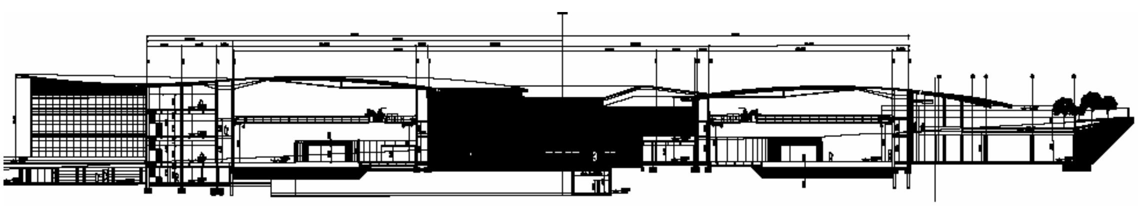
Table 1. Loads and requirements on the critical floor area

These necessities and requirements are incorporated in the final solution adopted for the critical floor area.

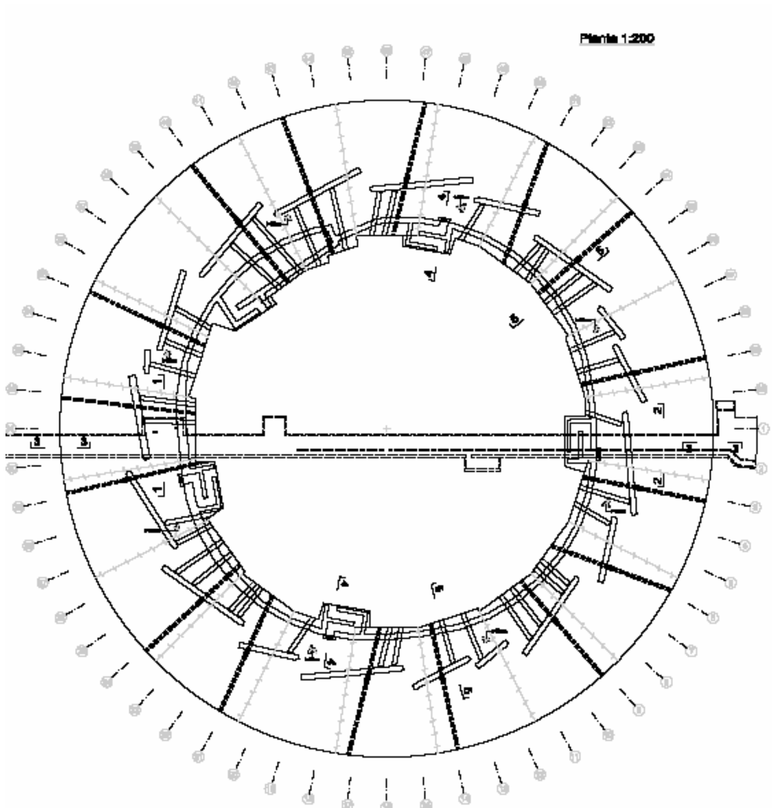
3.- Critical Floor area foundations solution

Design

Figures below are showing part of the ALBA building executive project were we can see a cross section of the buildings and the top view of the critical floor area.



Cross section of the ALBA buildings

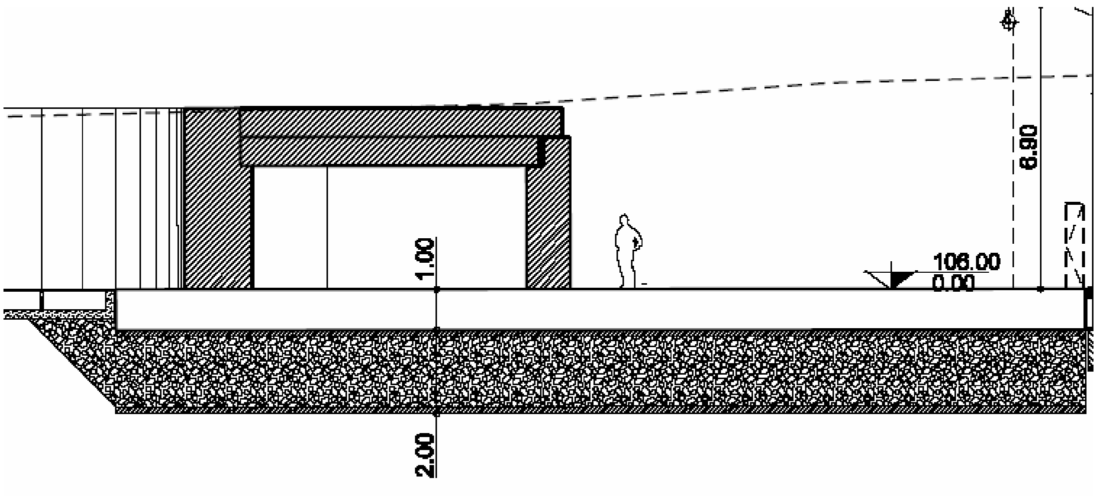


Top view of the critical floor area with the walls af the ALBA tunnel and the sectors of the slab

The detailed design of the critical floor slab takes into account the effect of differential subsoil movements as described above and the effect of vertical loads, acting on the test slab (dead weights and live loads).

The solution projected for the critical slab floor area of the ALBA Synchrotron Light Source consists in 1 meter thickness concrete slab, supported on a 2 metres thickness treatment soil.

This underlayer will consist in a refill of 1,70 meters of selected gravel (20 to 40 mm diaameter) homogenously and conveniently compacted protected by two layers of 0,15 meters of poor concrete, on the top and the bottom (sandwich mode) of this gravel.



Cross section of the solution for the critical floor area

Construction Stages

The whole test plate, which has been divided into 20 segments, will be produced one by one. The area of the single elements has been chosen in such a way that the corresponding concrete volume can be poured in one day and the corresponding work properly be guaranteed.

Construction joints to be vertical with shuttering boards (or similar) and longitudinal reinforcement bars going through the shuttering. Surface retarder will be applied to the shuttering prior to pouring. Immediately the formwork is removed, concrete surface will be washed off with a strong water jet to expose the aggregates.

After-treatment of the exposed concrete surface during at least the first week after pouring will be applied to avoid a desiccation of the surface. Could be curing or better covering the slab with plastic or insulating foils.

The time gap between pouring two adjacent elements shall be at least one week (hardening of the prior poured element).

4. Ground vibration measurements at ALBA site

The ground vibration measurements at ALBA site done from 5th to 7th May 2008 by Desy group were made using Güralp tri-axial digital force feedback broadband seismometers CMG-6TD.

These seismometers measure the ground acceleration which is integrated internally. The CMG-6TD seismic sensors are hermetically sealed three-axis devices with an internal 24 bit digitizer and a seismometer constant of C_S = 2 kV/m/s. The resolution of the instruments is about 0.09 nm/bit @ 1 Hz, which is sufficient to resolve the power spectra even at medium noise sites.

The ground vibration was measured on 2 campaigns described on the following table.

DATE/CASE	POSITION	OBSERVATIONS
5TH May 2008/ 1	Warehouse	Cultural noise, factory, jackhammer, truck
6th May 2008/ 2	ALBA building	Cultural noise, factory, jackhammer, truck

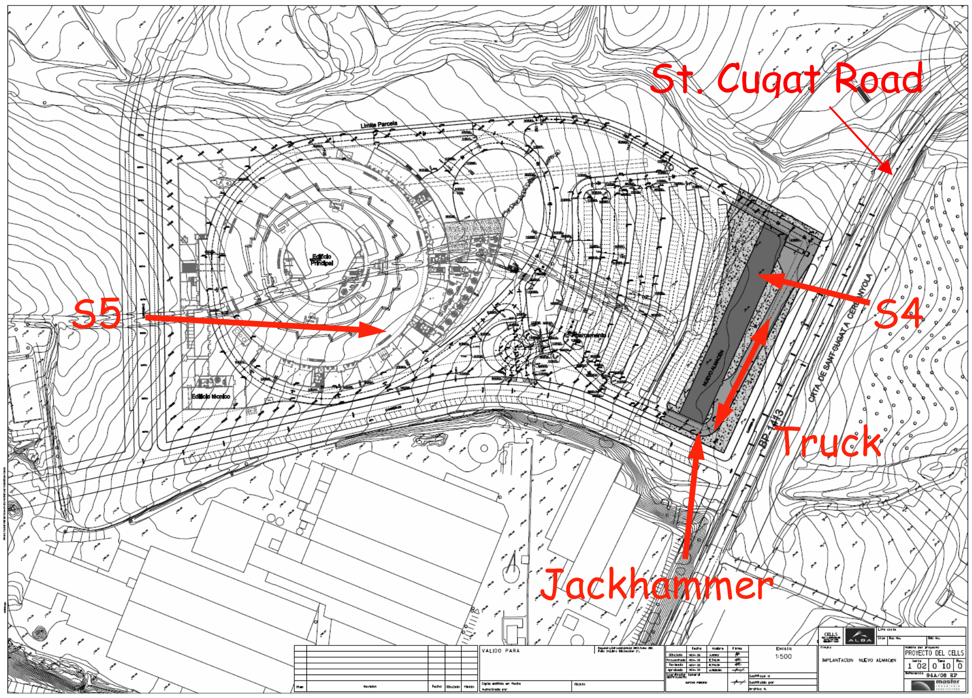
The ceramics factory activities schedule was

	MILL 2			**MILL 3**	
DATE	*ON*	*OFF*		*ON*	*OFF*
5TH May 2008	7:00	9:30		13:00	20:45
	10:15	13:30		22:00	5:20
6th May 2008	6:05	9:30		14:30	20:45
	10:15	13:30		22:00	5:20
	14:09	18:30			
	19:05	19:33			
	22:07	1:45			

The sensors and the computer were powered by the mains of the site via long cables.

Case 1

The position of the sensors is described on the following graphic



Warehouse, traffic at St. Cugat Rd.

Difference between traffic at 17:50 and at midnight, 00:05 (15 minute averages):
@ 1 Hz, 79 nm vs. 20 nm respectively. 12 Hz, 16 Hz, 24 Hz lines are seen in the midnight spectra, most probably due to motors running in the ceramic factory.

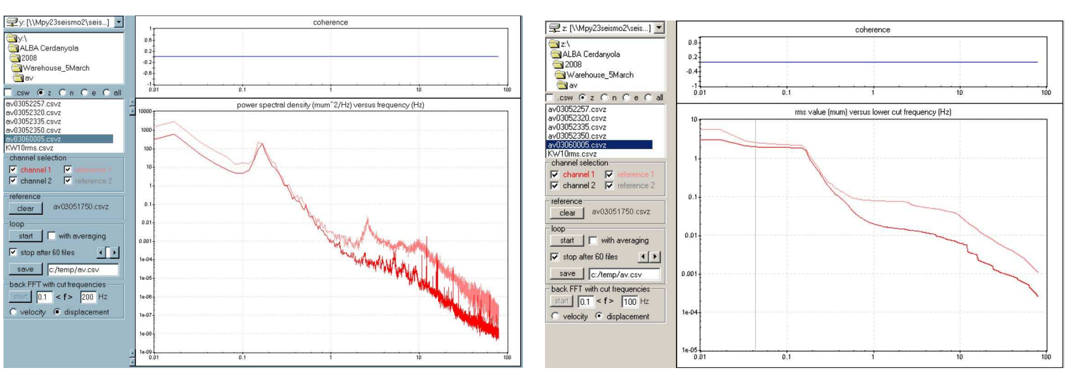


Fig. 1

However, as seen from 1 minute files, instantaneous variation can be substantial:
For example, at 17:56 a 2.6 Hz bump due to traffic, @ 1Hz 123 nm, is recorded.

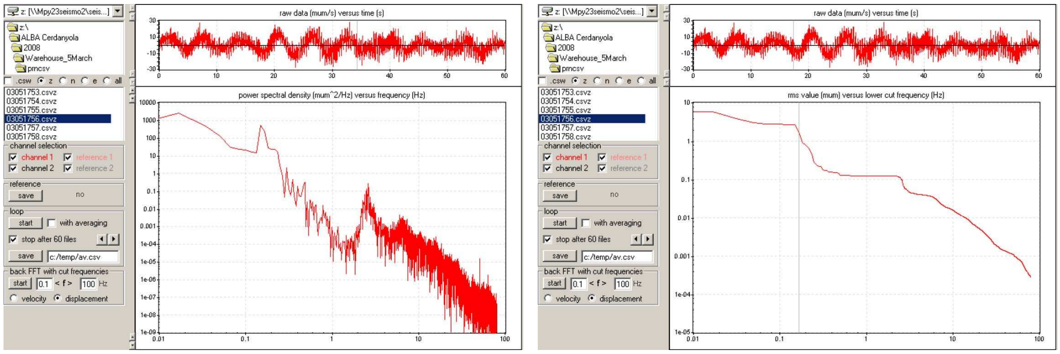


Fig. 2

Or at 20:44, two bumps at 6 & 10 Hz are visible, 51 nm @ 1 Hz (Fig. 3). The next minute (20:45), this value falls down to 24 nm and the bump at 10 Hz vanishes (Fig. 4).

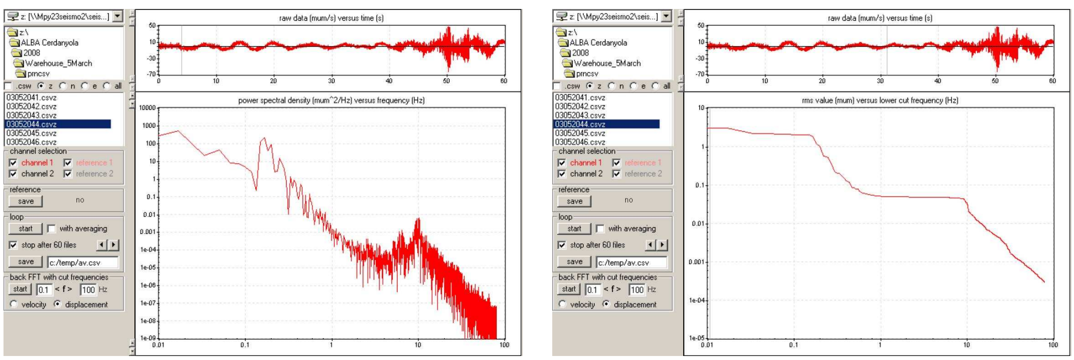


Fig. 3

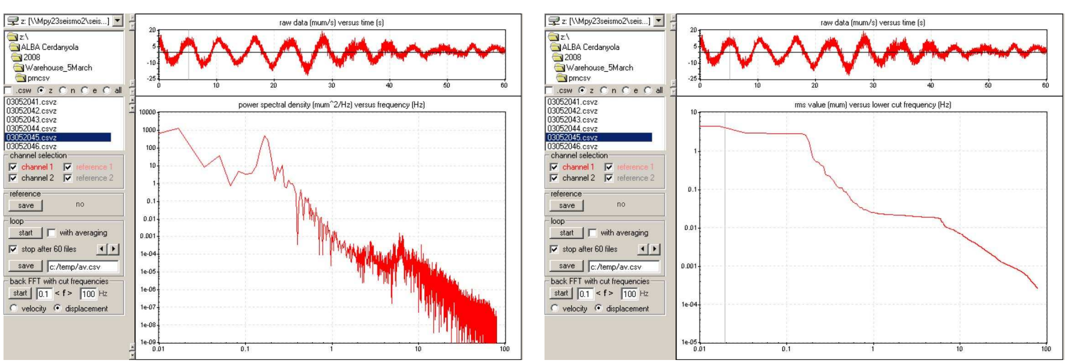


Fig. 4

Slab, traffic at St. Cugat Rd. only

The slab registers the traffic as it is low frequency noise, but the amplitudes are lower. However, there are instantaneous fluctuations, for example at 20:47, 67 nm at 1 Hz is registered and a very clear bump at 6 Hz, due to traffic in St. Cugat Rd. is seen (Fig. 5). At 20:50, no traffic signal is observed, 40 nm @ 1 Hz (Fig. 6). Lines at 12 Hz & 16 Hz are due to motors running at a factory nearby.

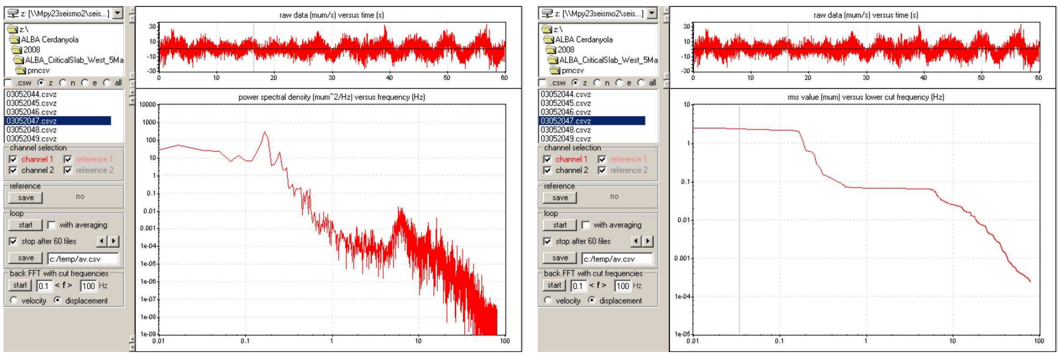


Fig. 5

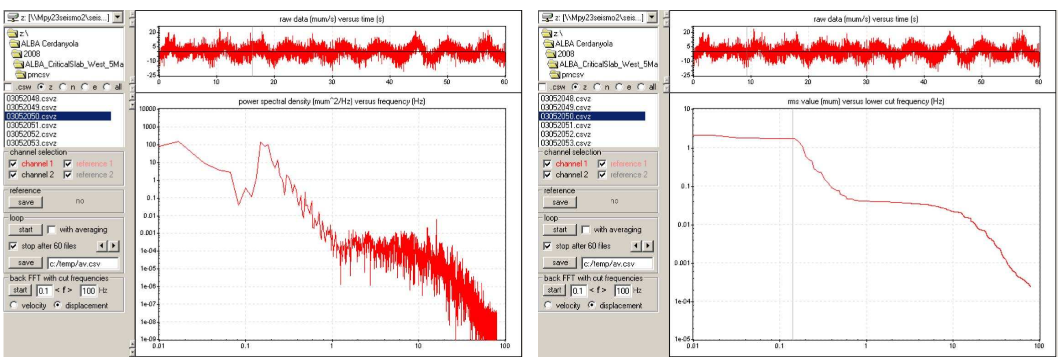


Fig. 6

Warehouse, traffic simulated by the truck.

Truck driving on the road nearby the warehouse could simulate the traffic in the late afternoon. Traffic at 17:50 @ 1 Hz is 79 nm compared with truck at 21:57 which is 69 nm at this frequency region.

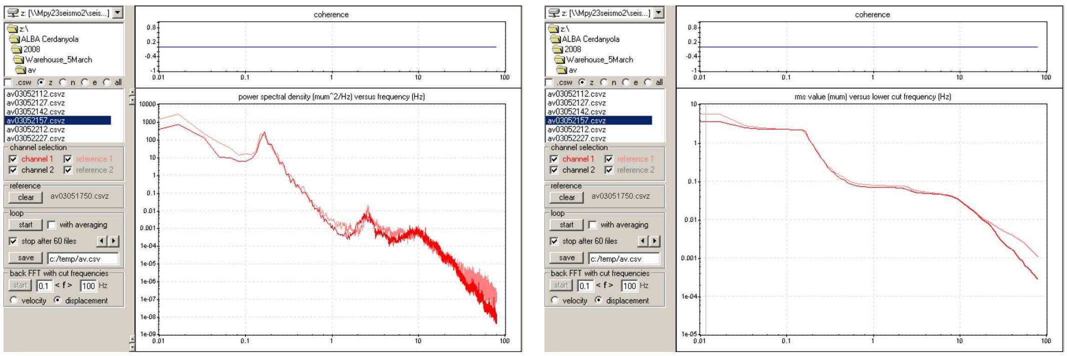


Fig. 7

Minute-by-minute fluctuations are larger. For example, at 21:39, 85 nm @ 1 Hz was measured (Fig. 8). The very next minute, 21:40, this value drops to 29 nm (Fig. 9). The bump at 2.5 is due to the truck. During day time, this effect will be much more severe.

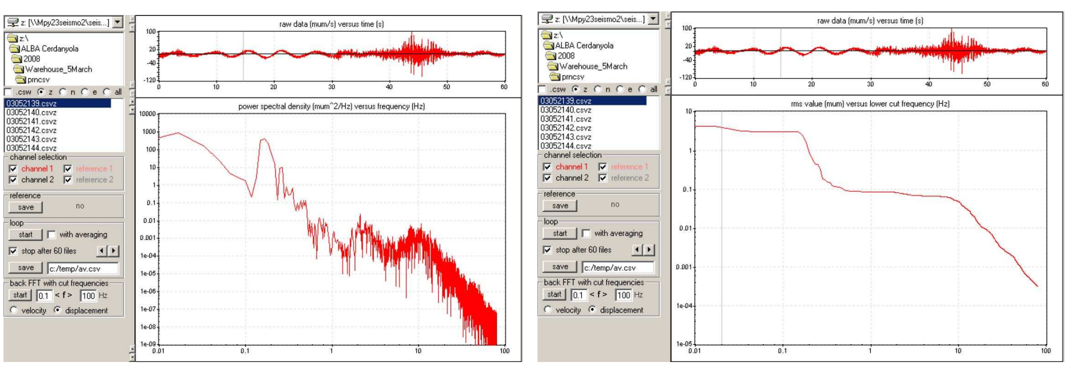


Fig. 8

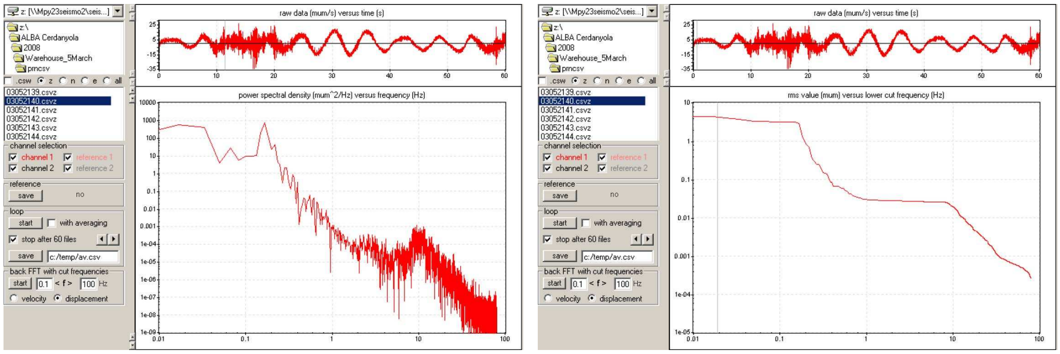


Fig. 9

<u>Slab, traffic simulated by truck</u>

Smaller amplitude of vertical vibration is registered as the truck drives on the dirt road besides the warehouse compared to the warehouse case. Two lines @ 16 and 24 Hz are however detected on the slab which are due to the motors of the factory nearby. @ 1 Hz, the slab registers a movement of 37 nm at 21:20, and the ware house 68 nm at 21:27 (15 minutes average files).

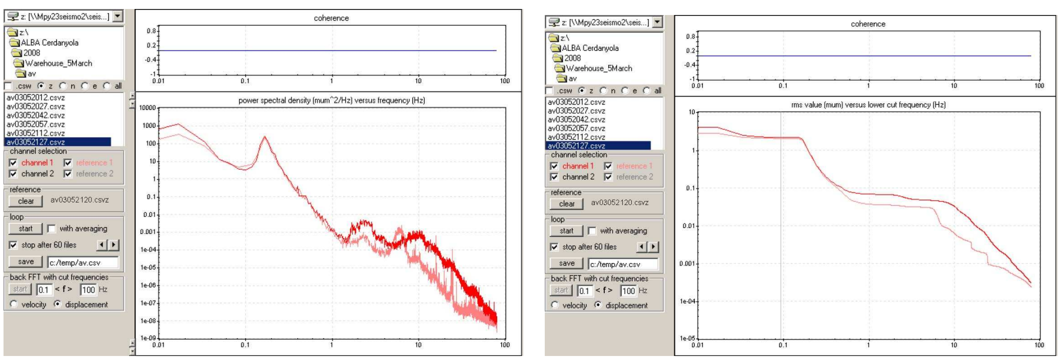


Fig. 10

<u>Comparison of amplitudes of vibration caused by jackhammer nearby the warehouse and on the ALBA slab</u>

The slab dampens all high frequency components generated by the jack hammer. For example, at 23:27, the vertical vibration amplitude @ 1 Hz is 81 nm measured in the warehouse and only 44 nm on the slab (Fig. 11).

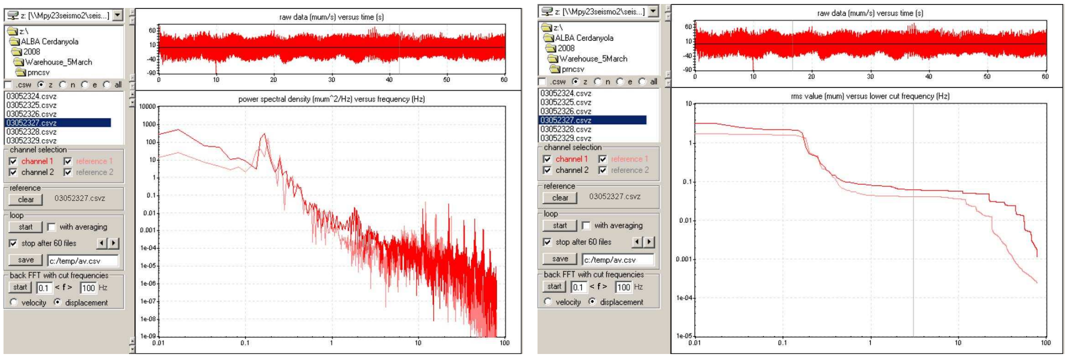
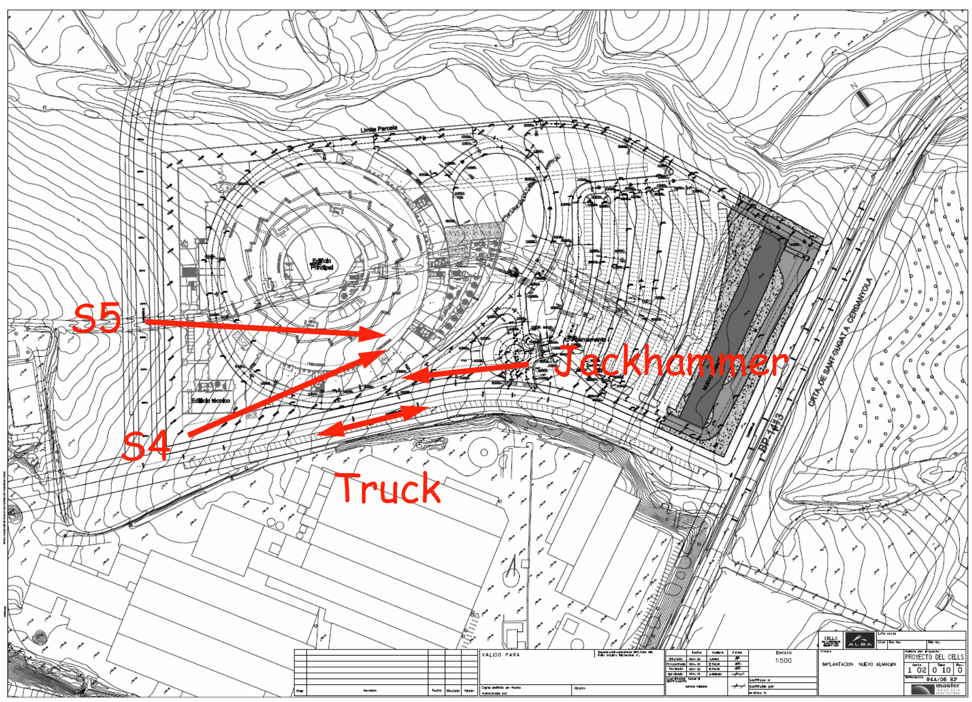


Fig. 11

Case 2

The position of the sensors is described on the following graphic



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<u>Comparison of amplitudes of vibration caused by jackhammer nearby the 'normal' slab corridor and on the ALBA slab</u>

Difference between 'normal' and the 'critical' slabs: A jackhammer was used to generate high frequency noise (> 10 Hz). Many peaks are seen at 11, 18, 22, 33, 44, 55, 68 Hz which are due to jackhammer, plus the lines at 15, 16, 18, 20 Hz due to mills and motors of the ceramic factory. However, @ 1Hz, 41 nm of vibration is registered on the critical slab compared with 135 nm on the normal slab at similar times ~ 23:30. The critical slab seems to dampen high frequency technical noise.

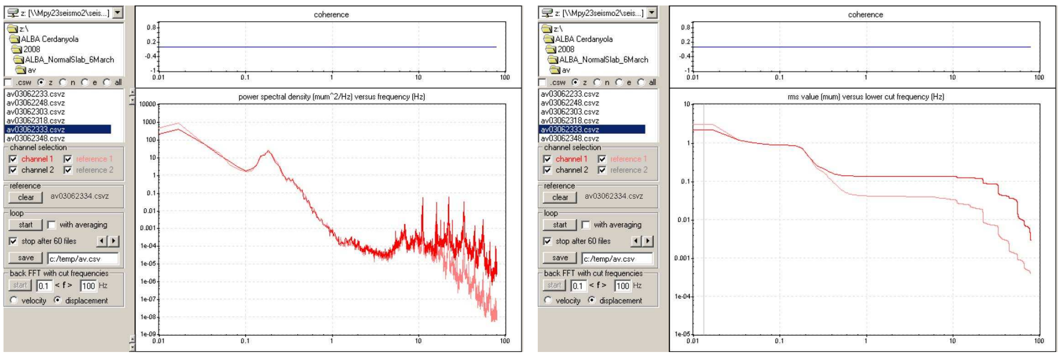

Fig. 12

Effect of normal traffic

A comparison of 15 minute average files taken at 20:04 for the critical slab and 20:07 at the corridor, shows that yet again, the ALBA slab dampens high frequency noise, but the low frequency noise, e.g. Due to traffic is not affected. @ 1 Hz, the amplitude measured for the critical slab is 54 nm, and at the corridor, 64 nm (Fig. 13).

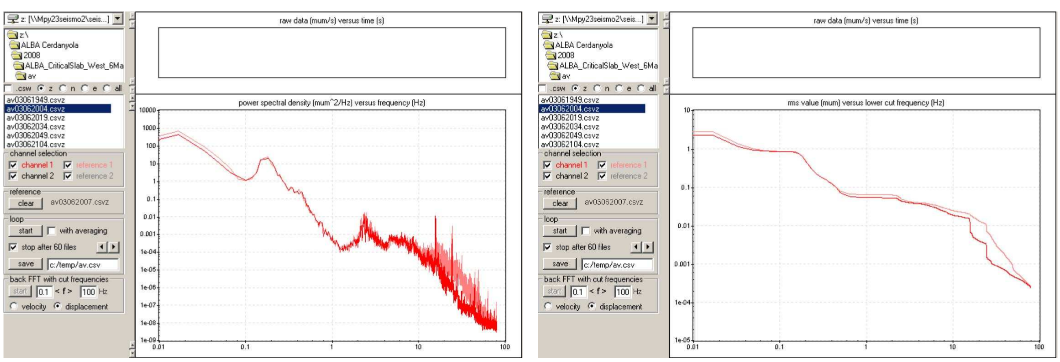

Fig. 13

Effect of noise caused by the truck driving on the road nearby the corridor

A similar result to the previous section is obtained when traffic is simulated on the road nearby the critical slab (West) and the corridor. Fig. 14 shows a 15 minute average taken for the normal slab at the corridor taken at 22:33 and for the ALBA slab at 22:34. @ 1 Hz, the amplitude of the vibration is 65 nm and 52 nm respectively.

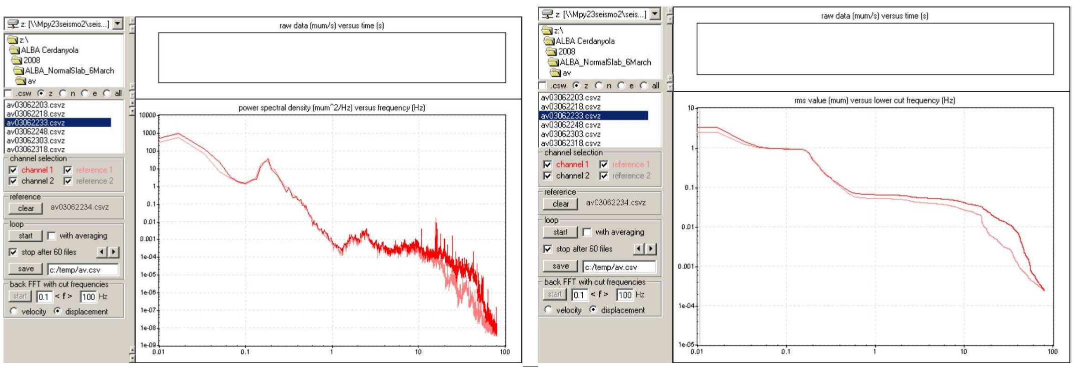

Fig. 14

4.- Summary

The vibrations response of the ALBA critical floor area has been measured. The cultural noise around the site has been characterized and its levels measured.

The foundations solution adopted has displacement dumping effect when increasing the frequencies of the excitations reaching up to a factor 2,5 . At low frequencies no duping effect is detected.

The level of cultural noise at the side is significant and confirms the first results obtained on the 2004 measurements campaign. However, the dumping effect reduces the typical peaks around 125 nm detected outside the critical floor area to around 50 nm on the critical floor area slab.

Provisions in order to decrease the effect of the traffic on the roads around the site are desirable. Recommendations have been passed to the authorities responsible of the execution of the urbanization works around the site to minimize the effects of the traffic.

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